A Method of Transmitting Synchronous Transport Modules via a Synchronous Transport Network

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This application is based on and claims the benefit of European Patent Application No. 00440160.0 filed Mai 26, 2000, which is incorporated by reference herein.

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Field of the Invention

The invention relates to a method of transmitting, via a
15 synchronous transport network, a frame-structured synchronous multiplex signal, being composed of transport frames having a payload section and an overhead section, in the payload section of which multiplex units are multiplexed in accordance with a multiplex hierarchy, and
20 to a multiplexer for a synchronous transport network which is adapted to transmit a frame-structured, synchronous multiplex signal of this type.

Background of the Invention

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A synchronous digital transport network operates for example in accordance with the recommendations of the ITU-T (Telecommunication Standardization Sector of International Telecommunication Union) for SDH (Synchronous Digital
30 Hierarchy) or SONET (Synchronous Optical Network), useful information being packed in so-called containers. The containers contain an overhead section known as "path overhead" together with which they are referred to as virtual containers VC-N. There are virtual containers of
35 the types VC-11, VC-12, VC-2, VC-3 and VC-4. There are also contiguously concatenated containers of the types VC-4-4c and VC-4-16c in the case of SDH, and VC-3-3c,

VC-3-12c and VC-3-48c in the case of SONET. The virtual
containers represent multiplex units and are multiplexed in
a frame referred to as synchronous transport module STM-N
(N - 1, 4, 16 or 64), the virtual containers being able to
5 be arbitrarily positioned in the payload section of the
transport modules and addressed by a pointer in the
overhead section of the transport modules. Smaller virtual
containers here are always multiplexed in larger virtual
containers. A synchronous transport module in SDH for
10 example always comprises a virtual container VC-4, or in
the case of contiguously concatenated containers, a
VC-4-nc (n = 4 or 16). On the other hand, in the case of
SONET each transport module always contains three VC-3s,
and in the case of contiguously concatenated containers a
15 VC-3-3c, which corresponds to a VC-4, a VC-3-12c or a
VC-3-48c. The described multiplex hierarchy of SDH and
SONET is described in detail in ITU-T G.707 (3/96) Chapter
6.

20 Communications signals transmitted in a synchronous
transport network of this kind are thus frame-structured,
synchronous multiplex signals being composed of frames each
having a payload section and an overhead section.
Multiplex units are multiplexed in the payload section of
25 each transport frame in accordance with the multiplex
hierarchy specified by the ITU-T. The overhead section
contains a pointer to the largest multiplex unit contained
in the payload section and one section referred to as RSOH
(regenerator section overhead) and one section referred to
30 as MSOH (multiplex section overhead). These contain items
of check- and control information which in the case of the
RSOH are terminated and regenerated by each regenerator and
in the case of the MSOH by each multiplexer. Amongst other
things, management functions of the network management
35 system are performed with the aid of these items of check-
and control information.

Increasingly, synchronous transport networks are being used not only by public network operators but also as company networks with company network management systems. If a plurality of SDH- or SONET-based sub-networks of a company

5 network are to be connected via the transport network of a public operator, different use of the check- and control information from RSOH and MSOH can lead to conflicts between the network management systems of company transport network and public transport network. Agreements on a

10 uniform use of the check- and control information are necessary and the network management system of the company transport network is restricted with regard to the management of its company network. Thus for example the multiplex structure cannot be changed from 16 x VC-4 to

15 1 x VC-4-16c in a STM-16 without the agreement of the public network operator.

Optical networks via which so-called optical channels (OCh) are to be transmitted are also currently in development.

20 These networks are to be capable of transparently transmitting signals with any bit rate and therefore these future optical networks will also be capable of transparently transporting frame-structured communications signals from a company network. However as yet no binding

25 standard exists for this purpose and moreover the construction of such an optical network would require the replacement of all the network elements.

Summary of the Invention

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An object of the invention is to provide a method with which it is possible to use the current SDH- or SONET-based transport networks to connect synchronous digital sub-networks of private operators without the need for

35 agreements between the network management systems and without restrictions upon the private operator. Another objective of the invention is to provide a multiplexer for

a synchronous transport network with which frame-structured synchronous multiplex signals, being composed of frames having a payload section and an overhead section in the payload sections of which multiplex units are multiplexed

5 in accordance with a multiplex hierarchy, can be transmitted without the need to access the overhead section of the transport frames to be transmitted.

The object is achieved by mapping the frames to be

10 transmitted, including their unchanged overhead sections, as payload in a concatenation of newly formed multiplex units.

With respect to the multiplexer, this object is achieved by

15 a multiplexer for a synchronous digital transport network, which has at least one tributary input, a multiplex device, and at least one output. The tributary input receives a first frame-structured synchronous multiplex signal which is composed of first frames each having a payload section

20 and an overhead section. The multiplex units are multiplexed in the payload sections in accordance with a multiplex hierarchy. The multiplex device is connected to the tributary input. It serves to create new multiplex units, to concatenate the newly formed multiplex units to

25 form a concatenation, and to pack the received transport frames, including the unchanged overhead sections thereof, as payload in the concatenation of the newly formed multiplex units. The one output creates and transmits a second, frame-structured synchronous multiplex signal

30 composed of second frames in whose payload sections the concatenated, newly formed multiplex units are inserted.

An advantage of the invention is that it facilitates the construction of SDH- or SONET- based virtual private

35 networks (VPN). Other advantages are that it is also possible to transmit frame-structured synchronous communications signals in the case of which overhead bytes

are used proprietarily, i.e. not in accordance with the ITU-T recommendations, that RSOH, MSOH and pointer values remain in the overhead section of the transport frames to be transmitted, and that therefore in the transmission of

5 such frame-structured synchronous communications signals the same effect is achieved as would be achieved with the planned optical networks but without the need to replace the existing network elements in the public transport network.

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Another advantage of the invention consists in that the private network operator can set up protection circuits, such as MSP (Multiplex Section Protection, ITU-T G.841, 10/1998, Section 7.1) or MS-SPRING (Multiplex Section

15 Shared Protection Ring, ITU-T G.841, 10/1998, Section 7.2) between its sub-networks.

The invention can also be used advantageously for the switching of frame-structured communications signals within

20 a network element.

Brief Description of the Drawings

In the following the invention will be described in several

25 exemplary embodiments making reference to Figures 1 to 8 in which:

Figure 1   illustrates sub-networks of a private network operator which connects its sub-networks via a public

30 transport network,

Figure 2   illustrates the multiplex structure for the process according to the invention for a SDH-based transport network,

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Figure 3   illustrates the multiplex structure for the
            process according to the invention for a SONET-
            based transport network,

5 Figure 4a, b
            illustrate a first example for the mapping of
            frames of the type STM-4 in a SDH-based transport
            network,

10 Figure 5a, b
            illustrate a second example for the mapping of
            frames of the type STM-16,

    Figure 6   illustrates the construction of a virtual private
15   network with the arrangement according to
                Figure 1,

    Figure 7   illustrates the logical construction of the
                virtual private network according to Figure 6 and
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    Figure 8   is a block diagram of a multiplexer according to
                the invention.

Detailed Description of the Invention
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    Figure 1 shows an application of the invention as first
    exemplary embodiment. Two sub-networks SN1 and SN2 and one
    individual network element R6 of a private operator are
    connected to one another via a public transport network
30 WAN. The first sub-network SN1 contains three network
    elements R1, R2 and R3 which are connected to form a ring
    network. The second sub-network SN2 contains two network
    elements R4 and R5 which are connected to one another via
    two redundant lines. The network elements are
35 interconnected within the sub-networks SN1, SN2 via SDH
    interfaces via which the frame-structured synchronous

multiplex signals are transmitted. The multiplex signals
consist of synchronous transport modules of the type STM-4.

Each of the network elements R1-R6 is an IP router in each
5 case of a data network via which a plurality of IP-capable
terminals of the operator are interlinked. The SDH-
connections within the sub-networks represent the
operator's backbone network via which the IP-traffic
between the data networks is handled for example by means
10 of the method for "IP via SDH" known from IETF RFC 1619 and
1661.

The sub-networks SN1, SN2 and the individual router R6 are
now likewise to be capable of exchanging transport modules
15 of the type STM-4 via the transport network WAN in order
that the sub-networks are connected to one another. For
this purpose it is necessary for the transport modules to
be transmitted unchanged between the sub-networks, i.e.
without terminating the overhead of the transport modules
20 in the transport network WAN, so that the operator's
backbone network is not subject to any restrictions
regarding the use of the overhead bytes.

A basic principle of the invention is now to transmit the
25 synchronous transport modules in transparent fashion as
payload in a concatenation of virtual containers. For this
purpose new multiplex units of the type VC-4 are formed in
the transport network and concatenated with one another to
form a virtual concatenation VC-4-nv. The transport frames
30 to be transmitted between the sub-networks are packed as
payload into the payload sections of the multiplex units of
this virtual concatenation. The newly formed multiplex
units are then embedded in the payload section of newly
formed transport modules and transmitted via the transport
35 network WAN.

The mapping illustrated in Figure 2 is used for this purpose. Figure 2 shows a container C-4 which, by the addition of an overhead section known as POH (path overhead), is extended to form a virtual container VC-4.

5 The container C-4 contains data of a payload signal which are to be transmitted. The virtual container VC-4 represents the multiplex unit. By the addition of a pointer indicating the phase position of the virtual container VC-4 in a superordinate transport frame, the VC-4

10 becomes a so-called AUG (administrative unit group).

Alternatively, as shown in the second from bottom line of the Figure, an AUG can also contain a container of a contiguous concatenation C-4-nc. Such contiguous

15 concatenations are used when, in a transport module STM-N (N = 4, 16 or 64) which is greater than a STM-1, the payload sections of the containers C-4 contained therein are to be jointly used for one single transmission channel. At this point it should also be noted that the

20 nomenclature of the draft version of ITU-T G.707 (Temporary Document 48R1 (PLEN), 4/00), currently discussed in ITU-T SG15, differentiates the AUG into AUGN (N = 1, 4, 16) corresponding to the size of the transport module in which the AUG is transported. Accordingly a STM-16 always

25 contains an AUG16. This AUG16 can contain either a contiguous concatenation of 16 VC-4s (VC-4-16c) or however four byte-wise interleaved AUG4s. The AUG4s can in turn contain either a contiguous concatenation VC-4-4c or four type-wise interleaved AUG1s.

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In a next step a transport frame STM-N is formed, where N can be 1, 4, 16 or 64. For N = 1, as already mentioned, the transport frame contains an overhead section comprising MSOH, RSOH and pointer, and a payload section. The payload

35 section comprises exactly one AUG1 and the pointer addresses the start of the VC-4 in the payload section. Higher transport frames (N = 4, 16, 64) are formed by byte-

wise interleaving of N AUG1s to form AUGN. A STM-N thus
contains exactly one AUGN which in turn contains exactly N
AUG1s in accordance with the described multiplex rule. The
manner in which the AUGs are interleaved in the STM-N is
5 described in detail in the draft version of ITU-T G.707
(Temporary Document 48R1 (PLEN), 4/00 Chpt. 7.1.

The thus formed transport frame STM-N is now periodically
repeated with a frame clock, where each new frame naturally
10 contains new data bits of the payload signal to be
transmitted. The synchronous data stream formed from the
periodically repeated transport frames is transmitted in
the sub-networks of the private operator and transports all
the payload data, i.e. in the exemplary embodiment the IP
15 packets, which are transmitted between the individual
routers in the operator's backbone network. This data
stream is now also to be transmitted as a whole via the
public transport network WAN in order to connect the sub-
networks SN1, SN2 and the individual router R6 to form a
20 whole network.

For this purpose, at the interface between public transport
network and private company network new multiplex units
VC-4 are generated by the multiplexer and concatenated to
25 form a virtual concatenation VC-4v. Such a virtual
concatenation of virtual containers VC-4 is known *per se*
and described in ITU-T G.707 Chpt. 8.1.7. The number of
multiplex units in the concatenation is dependent upon the
size of the transport module to be transmitted. If, as in
30 the exemplary embodiment, a STM-4 is to be transmitted, the
public network operator requires five multiplex units of
the type VC-4. Two VC-4s would be required for STM-1,
seventeen VC-4s for STM-16 and sixty eight VC-4s for STM-
64. In the mapping shown in Figure 2 this is schematically
35 indicated by parallel paths in the flow diagram.

The virtual containers VC-4 of the concatenation are now
combined to form a new AUG in accordance with the above
described multiplex rule. As is known, a STM-N can
accommodate exactly N VC-4s. As the number of concatenated
5 containers (2, 5, 17 or 68) does not correspond to the
permissible values for N (1, 4, 16, 64), the next larger
transport frame must be used. The remaining capacity of
the transport frame can be filled with further multiplex
units VC-4. This is illustrated in Figure 2 by a further
10 tributary for the upper AUG.

As this is a virtual concatenation, alternatively to a next
larger transport frame it is also possible to use several
smaller transport frames. The individual multiplex units
15 of the virtual concatenation thus need not necessarily be
transmitted via the same interface but can also take
different paths through the transmission network, transit
time differences being compensated by intermediate storage
in the receiving network element. However it is
20 advantageous to transmit the virtual concatenation in one
single transport module as this minimizes the transit time
differences.

Now a new transport frame STM-N is formed and the AUG is
25 embedded in the payload section of this new transport
frame. The periodic repetition of this transport frame
always with a new payload gives rise to a new synchronous
data stream which is transmitted via the transport network
WAN of the public operator. In the transmission the
30 overhead of the newly formed transport frames is
exclusively available for control and management functions
of the public transport network. In accordance with the
ITU-T recommendations the public operator can access the
overhead bytes with no further restrictions without
35 conflicting with the network management system of the
private operator, as the transport frames formed by its

network elements, together with overhead, are transported as payload through the public transport network.

Figure 3 illustrates the corresponding mapping for a SONET-
5 based transport network. Instead of a VC-4, in SONET one always uses three VC-3s which are combined to form an AUG. In SONET the transport modules are known not as STM-N but as OC-N (optical) or STS-N (electrical) where N = 3, 12, 48 or 192. Similarly to a STM-N, they also contain a RSOH and
10 a MSOH in the overhead section. However they include not only one pointer, but, in accordance with the number of multiplex units of the highest hierarchy stage (VC-3), three pointers to the three VC-3s of the AUG. The number of virtual containers VC-3-Xv for the transport modules
15 OC-3, OC-12 and OC-48 which are to be virtually concatenated for the transport is shown in the Figure.

In addition to the mappings illustrated in Figures 2 and 3, mixed forms are also possible, in the case of which for
20 example the private operator runs a SONET-based network and connects its sub-networks via a SDH-based transport network of the public operator.

Figures 4a and 4b schematically illustrate how in the first
25 exemplary embodiment the transport frames from the private network which are to be transported are embedded in the public operator's concatenated multiplex units which are to be newly formed. Figure 4a firstly shows the construction of the STM-4 of the private operator. The construction
30 corresponds to the specifications of ITU-T G.707. The STM-4 has one single overhead section with a length of N*9 columns and one single payload section containing an AUG4 formed by byte-wise interleaving of four AUG1s. However for greater clarity a different designation has been
35 selected in Figure 4a. It should be noted that here merely a different designation has been selected while the actual

construction in the exemplary embodiment corresponds to the rules of ITU-T G.707.

As illustrated in Figure 4a, the STM-4 consists of four
5 byte-wise interleaved frames of the type STM-1**. The designation STM-1** was selected to indicate that these are not STM-1 frames, although the STM-1** frames formally correspond to a STM-1 frame in construction and appearance.
     For clarity the four STM-1**s have been illustrated not in
10 interleaved but serial form.

Each of the four STM-1**s consists of an AUG1 and a part of the overhead section of the STM-4. As already stated, the STM-4 contains only one single overhead section consisting
15 of 4*9 columns. However in Figure 4a this overhead section has been shown split into four equal parts, one quarter of the overhead section in each case being assigned to one STM-1** as overhead of this fictive frame. As the four STM-1**s are interleaved byte-wise, the four parts exactly
20 form the actual overhead section of the STM-4.

The overhead section consists of RS-OH, MS-OH and AU-pointer AU-PTR. The designations for each of the overhead sections of the four STM-1**s have also been chosen
25 accordingly in Figure 4a. The overhead section is adjoined by the payload section which, in accordance with the fictive division into four STM-1**s, has likewise been shown divided into four parts, one part of the payload section in each case being assigned to one STM-1**. Each
30 of the parts of the payload section contains a virtual container VC-4 consisting of a container C4 and a container overhead POH. However, for clarity, and without limiting the generality, in the Figure the containers contained in the payload section have been shown directly adjoining the
35 overhead section of the transport frame, i.e. in the exemplary embodiment the AU-pointers would all be zero. In actuality the VC-4 can be arbitrarily positioned in the

payload section of a STM-1** and extend into the payload
section of the following frame. This is a basic
characteristic of synchronous transport networks (SDH,
SONET): Clock differences between individual network
5 elements of the transport network are compensated by AU
pointer justification and corresponding displacement of the
virtual container.

A STM-1** has 9 rows and 270 columns. The columns 1-9 are
10 occupied by the quarter of the overhead section assigned to
the STM-1** while the other columns 10-270 represent the
part of the payload section assigned to the STM-1**.

Figure 4b illustrates the five virtual containers VC-4v of
15 the virtual concatenation VC-4-5v. The upper part of the
Figure provides a detailed view of the first virtual
container VC-4v#1, while the other four virtual containers
have been illustrated in reduced form. In reality however
all five virtual containers are of the same length.
20
Each of the virtual containers is assigned an AU-pointer
AU-PTR-v1, ..., AU-PTR-v5 indicating its phase position in
the superordinate transport module. VC-4 and AU-pointer
represent an AUG1. Since this is a virtual concatenation,
25 all five AU-pointers are determined independently of one
another as the five VC-4s can be transmitted in any phase
position relative to one another. The column numbers of 1
to 261 are indicated at the upper edge of the VC-4 and the
row numbers of 1 to 9 of the AUG are indicated at the
30 right-hand edge.

The first VC-4 commences in column 1 with the POH (path
overhead). This is followed by the payload section of the
VC-4 in which the overhead sections of the STM-4 to be
35 transported are packed. Columns 2 to 10 contain the
overhead section of the first STM-1** from the STM-4,
columns 11 to 19 contain the overhead section of the second

STM-1**, columns 20 to 28 contain the overhead section of
the third STM-1**, and columns 29 to 37 the overhead
section of the fourth STM-1**. These are adjoined in
columns 38 to 41 by the container overheads POH of the four
5 multiplex units contained in the four STM-1**s. The other
columns 42 to 261 are reserved for proprietary or future
use by the network management systems of public and private
network operator and if they are not used are filled with
hexFF. By way of example it has been shown that columns 42
10 to 50 are reserved for the public operator and columns 51
to 269 for the private operator.

The second VC-4 of the concatenation likewise contains a
container head POH#v2. Adjoining the container overhead
15 the first container C4 from the STM-4 frame to be
transmitted is attached as payload. Correspondingly, the
third VC-4 of the concatenation contains the second
container C4 from the STM-4 frame, the fourth VC-4 contains
the third container C4 and finally the fifth VC-4 contains
20 the fourth container C4. In this way the entire payload
content of the STM-4 frame to be transmitted is distributed
between the virtual containers two to five of the
concatenation, while all the items of control information
from the overhead sections are embedded in the first VC-4.
25
The corresponding mapping for a transport frame of the type
STM-16 to be transmitted from the private network is shown
in Figures 5a and 5b. The STM-16 to be transmitted
consists of 16 byte-wise interleaved STM-1**s which each
30 contain a part of the frame overhead comprising RS-OH,
MS-OH and AU pointer. These in turn are in each case
adjoined by a virtual container of the type VC-4 consisting
of a container overhead POH and a payload section C4. Only
the first two STM-1** frames and the last, i.e. sixteenth,
35 STM-1** frame have been shown by way of example in
Figure 5a.

Figure 5b illustrates how this STM-16 frame is packed into a virtual concatenation of seventeen VC-4s. By way of example Figure 5b shows only the first three VC-4s and the last, i.e. the seventeenth, VC-4 of the concatenation. As

5 in the previous example the first VC-4 contains the frame overheads of the sixteen STM-1** frames of the STM-16 to be transmitted and the container overheads POH of the VC-4s from the STM-16. As in the previous example, the column numbers of the AUG are indicated at the upper edge and the

10 row numbers at the right-hand edge. The AU-pointer consists of nine bytes. In the first column of the AUG the VC-4 commences with its POH. Columns 2 to 10 contain the overhead section of the first STM-1** from the STM-16 to be transmitted, columns 11 to 19 contain the overhead section

15 of the second STM-1** etc. Finally columns 137 to 145 (137 = 2 + 15*9) contain the overhead section of the sixteenth STM-1** frame to be transmitted. This is adjoined in columns 146 to 161 by the container overheads POH of the STM-1** to be transmitted. Rows 162 to 261 are reserved

20 for proprietary or future use by the network management systems of public and private network operator and if they are not used are filled with hexFF. By way of example it has been shown that columns 162 to 170 are reserved for the public operator and columns 171 to 261 are reserved for the

25 private operator.

Figure 6 schematically illustrates how the transmission of the transport frames between the sub-networks of the private operator takes place via the public transport

30 network. This is based on the same arrangement as in Figure 1 but the public transport network WAN has been shown in detail. It consists of two ring networks connected to one another at two locations. The ring networks consist of network elements ADM, DXC which are

35 bidirectionally connected to one another. Such network elements are add/drop multiplexers ADM or digital cross-connects DXC. Each of the network elements R2, R4 and R6

of the operator interconnecting the private sub-networks
SN1, SN2 via the public transport network WAN are in each
case connected to an add/drop multiplexer of the public
transport network. By means of these add/drop
5 multiplexers, the transport frames to be transmitted
between the sub-networks SN1, SN2 and R6 are packed into a
concatenation of virtual containers in accordance with the
process already explained in detail, and are transmitted in
newly formed transport frames. Between the network
10 elements R2, R4 and R6 this gives rise to a virtual ring
network VR via which the multiplex signals structured into
STM-4 transport frames are transmitted.

For greater clarity Figure 7 shows a schematic detail view
15 of the virtual ring network VR. As the STM-4 frames are
transmitted transparently between the network elements R2,
R4 and R6 via the public transport network in that they are
treated as payload and packed into a concatenation of
virtual containers, for the private network operator this
20 is no different to a direct connection of its network
elements. Therefore from the standpoint of the private
network operator the network elements R2, R4 and R6 are
bidirectionally interconnected to form a ring network.
Thus in this virtual ring network in the case of a fault,
25 i.e. when the connection between two of the three network
elements fails, it is also possible to switch over to the
opposite direction in the ring and thus to re-establish the
connection in spite of the failure. A protection circuit
of this kind is referred to as MS-SPRING. Proprietary
30 rings and linear MS protection circuits can also be set up.

Figure 8 illustrates a multiplexer ADM with which the
transmission process according to the invention can be
executed. This is an add/drop multiplexer as used for
35 example in the public transport network WAN in Figure 6.
The multiplexer in each case comprises an east- and a west-
input IN_EAST, IN_WEST and an east- and a west-output

OUT_EAST, OUT_WEST which are connected to four optical
waveguides serving as east- and west lines of a
bidirectional SDH ring network. STM-16 frames are received
at the inputs and STM-16 frames are transmitted at the
5 outputs. In the inputs the received transport frames are
terminated, i.e. their frame overheads are evaluated and
the virtual containers of the type VC-4 contained in the
frames are forwarded to a central switching matrix (VC-4
matrix). In the outputs new transport frames STM-16 are
10 formed and the virtual containers received from the
switching matrix are packed therein. The multiplexer also
comprises a number of tributary inputs T_IN and outputs
T_OUT via which payload data can be inserted as virtual
containers into the ring network (add) or coupled out of
15 the ring network and fed to a connected user (drop).

The switching matrix serves to switch those virtual
containers which are not to be terminated in the
multiplexer ADM from the west-input to the east-output and
20 from the east-input to the west-output. Virtual containers
which are to be terminated by the multiplexer ADM (drop)
are switched from the relevant input via the VC-4 matrix to
one of the tributary outputs. Payload data which are to be
inserted by one of the tributary inputs into the ring (add)
25 are packed in a newly formed virtual container VC-4 in the
relevant tributary input and switched via the VC-4 matrix
to one of the outputs.

A data stream structured to form STM-4 frames is received
30 at the tributary input 81. In the input 81, in accordance
with the mapping described with reference to Figure 4a
and 4b, five virtual containers VC-4 are formed for each
received STM-4 frame and virtually concatenated to one
another. A STM-4 frame is in each case packed into these
35 five VC-4s. The concatenated, five VC-4-5vs are then fed
to the VC-4 matrix and fed from the matrix to a

corresponding output, e.g. the west-output OUT_WEST where
they are interleaved with other VC-4s in the STM-16 frames.

The opposite direction is illustrated by way of example at
5 the tributary output 82. The VC-4 matrix switches to the
output 82 a concatenation VC-4-5v of five VC-4s which for
example are contained in the STM-16 frame received at the
west-input IN_WEST. At the output 82 the useful
information of the five VC-4s is read out from the payload
10 sections thereof, intermediately stored in a buffer memory,
and assembled in the original phase position to form a
STM-4 frame which is then transmitted at the output 82. To
assemble the STM-4 frame, the frame overheads packed in
accordance with the mapping illustrated in Figure 4b are
15 read out from the first VC-4 and used as frame overheads
for STM-1 frames to be newly formed. Then the container
heads POH are read out and attached to the containers C4
contained in the payload section of the following four VC-
4s. Then the thus newly formed VC-4s are inserted into the
20 STM-1 frames in accordance with the value of the AU-pointer
present in the frame overhead and the STM-1 frames are
interleaved byte-wise to form a STM-4 frame. The
multiplexer ADM thus operates simultaneously as multiplexer
and demultiplexer.
25

The virtual concatenation of VC-4s for the transportation
of STM-N frames has been used throughout in the exemplary
embodiments. The virtual concatenation provides advantages
in the transmission as in interposed network elements no
30 attention need be paid to the phase position of the
individual concatenated VC-4s and thus no measures need be
taken to suppress differential phase fluctuations between
the VC-4s. However it is also possible to use a contiguous
concatenation of VC-4s for the transmission according to
35 the invention of STM-N frames. In SONET-based transport
networks a concatenation of VC-3s is used instead of the

concatenation of VC-4s since, as already mentioned [...]
the VC-4 [...].

The invention can also be used advantageously internally in
5 network elements in order to switch entire transport frames
using a switching matrix designed only for virtual
containers. In this case a received transport frame is
embedded in a concatenation of virtual containers at the
input end whereupon the virtual containers of the
10 concatenation are switched by the switching matrix to an
output where they are removed again and the original
transport frame is re-assembled. This facilitates the
switching of whole transport frames by a matrix which in
itself can only switch virtual containers. As a result the
15 frame overhead of the transport frames need not be
terminated at the input end and re-generated at the output
end.

At least in theory, the process according to the invention
20 can be iteratively interleaved as often as desired, i.e. a
first frame-structured synchronous multiplex signal can be
transmitted as payload of a first virtual concatenation in
a second frame-structured synchronous multiplex signal
which in turn is transported as payload of a second virtual
25 concatenation in a third frame-structured synchronous
multiplex signal etc.